FINAL MEMORANDUM

1. ADMINISTRATIVE:

Award Recipient: North Carolina State University

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Title: Assessment of terrestrial and aquatic monitoring programs in the southeastern United States [Global Change Monitoring Portal Phase 1]

Award No.: G12AC20508

Period of Performance: 9/20/12-6/19/15

Total cost: $174,261

2. PUBLIC SUMMARY:

Detecting change in ecosystems requires observations of living and non-living components over time. Many different organizations make observations that are relevant to understanding global change processes, but the data are often not easily discoverable by other interested scientists and managers. This project attempts to pull into a centralized location information about many of these observational networks. In this phase of the project, a publicly available web-based portal was developed that provides a means to discover, search, and connect to many types of environmental and biological data collected in the southeastern United States that are relevant to characterizing potential effects of climate and land use change on land, water, and wildlife. The Global Change Monitoring Portal consolidates information about data resources from research and monitoring done by federal, state, tribal, local, and non-governmental organizations; it provides opportunities for discovery by users who are land managers, scientists, tribal and other leaders, decision-makers, and citizens. Data resources can be visualized and searched by categories of measurements made and/or by specific geographic criteria such as state, ecoregion, hydrologic unit, and Landscape Conservation Cooperative. The GCMP provides a mechanism to increase the usefulness of important data collection efforts by a broad range of organizations by making the data more accessible to users.

3. TECHNICAL SUMMARY:

The goal of the project is to provide a centralized information source that allows users to discover, search for, and connect to data resources relevant to various land-management and science questions, especially related to changes in climate and land use. The sources of data include federal, state, tribal, local, and non-governmental. The metadata portal will provide background to support assessments of monitoring programs in the Southeast. The audience for the Global Change Monitoring Portal is primarily land managers and scientists, but the information is publicly available. This is a public service project that utilizes the results of other research and monitoring programs and serves as portal to information provided by these other programs.

The primary task was to compile, inventory, and map geographically, sources (federal, state, local and non-governmental) of atmospheric, terrestrial, water quality and quantity information and analysis capacity in the region to address climate and land use change issues. This was accomplished by development of a database of metadata for a range of monitoring programs/observational networks that collect or have collected data in the southeastern US, including the Caribbean. The metadata

includes details of observations made, purpose of sampling, sponsoring organization, period of record, classification of measurements made, program contact, and means of data access. Details of locations where observations are made are included when made available and are represented by point locations with a proximity descriptor; period of record is also included.

Results from this work will provide the region's scientists and decision makers with accurate and comprehensive information about monitoring networks that can be used to assess the potential effects of climate and land use change in the southeastern United States. The centralized inventory of monitoring programs will also contribute to a region-wide assessment of monitoring by a range of partners.

4. PURPOSE AND OBJECTIVES:

The purpose of the project was to provide a centralized, comprehensive catalog of information about monitoring networks associated with aquatic and terrestrial ecosystems that can be used to assess the potential effects of climate and land use change in the southeastern United States.

This project was developed to address a problem that emerged as a common issue among Southeast Climate Science Center partners as its science agenda was developed. The problem was that despite a lot of climate and ecosystem data being collected, it was difficult to know what observations are being made by what organizations and how to access the data. The intended solution was to bring information about the broad range of measurements made in ecosystems across the Southeast by many organizations into a centralized location. The goal was to make monitoring data more easily discoverable by interested scientists, land managers and decision-makers.

The tasks were originally proposed as

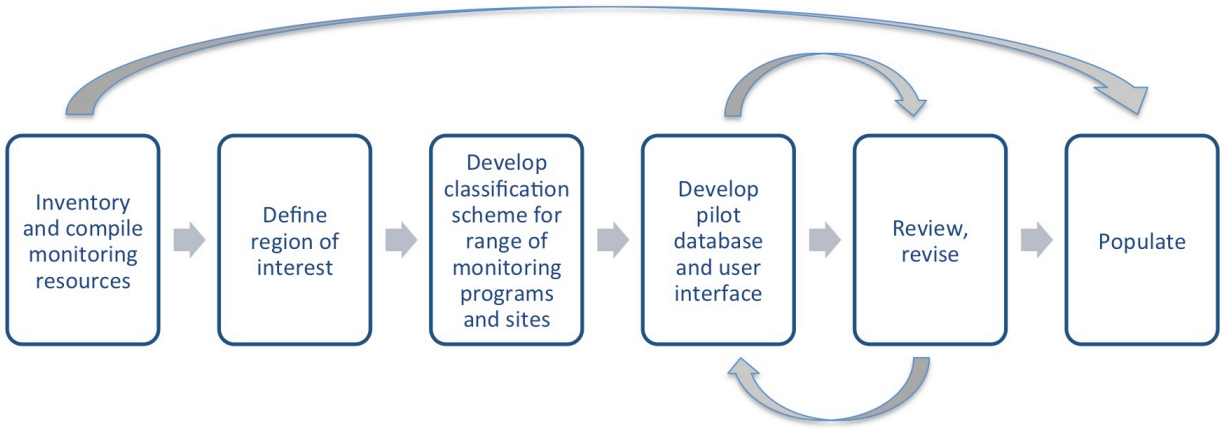
a) Compile, inventory, and map geographically, sources (federal, state, local and non-governmental) of atmospheric, terrestrial, water quality and quantity information and analysis capacity in the region to address climate issues;
b) Characterize the sources of information in terms of longevity and "depth", consistency over time, and types and quality of information;
c) Assess other attributes of the information sources to be identified;
d) Assess currently available information for use in tracking regional trends, or running scenarios of interest to federal, state and local resource managers;
e) Identify key information gaps of concern to federal, state and local resource managers.

This overall objective did not change and the development of a metadatabase and web portal was accomplished, fulfilling the first three proposed tasks. Characterization of data consistency and data quality was not feasible to incorporate in a consistent way for all the programs included in the inventory at this stage of development, but we incorporated program details, means to access their data, and a program contact, which should guide a user to be able to evaluate the suitability of a particular data resource for his/her purpose.

Because of the large amount of relevant data from disparate sources and varying accessibility, acquisition of some of the metadata elements of observational networks, and especially associated site information, required significant time and effort. Therefore the last two tasks related to overall assessment of the population of monitoring data were deferred to the second phase of the project.

5. ORGANIZATION AND APPROACH:

The following graphic summarizes the general approach used to develop the Global Change Monitoring Portal.



Inventory and compile monitoring resources. We utilized previous efforts that were undertaken to compile information about monitoring programs by us and other partners, as well as existing metadata portals and publicly available data warehouses, to develop a list of observational networks for which to derive metadata for our project. Examples of these groups and portals are National Monitoring Network Federal Monitoring Inventory, Ecosystems Interagency Workgroup, Albemarle-Pamlico National Estuary Partnership National Monitoring Network Pilot, NAWQA National Data Aggregation, SE Coastal Water Quality Monitoring Metadata Portal, NC Climate Retrieval and Observations Network of the Southeast Database, Water-CAT Florida Water Resource Monitoring Catalog. We focused on federal, state, local, tribal, and non-governmental networks of atmospheric, terrestrial, and water quality and quantity observations relevant to issues of global change. Additional programs for potential inclusion were also compiled from web-based and other research, and recommendations from agency contacts and colleagues.

Define region of interest. The geographic scope of this effort was initially proposed to include the states of North Carolina, Tennessee, Mississippi, Alabama, Georgia, and Florida and the Commonwealth of Puerto Rico. The geographic scope of the Global Change Monitoring Portal was later expanded to include the regions of five Landscape Conservation Cooperatives (Caribbean, Peninsular Florida, South Atlantic, Gulf Coast Prairie, and Gulf Coastal Plains and Ozarks) and part of a sixth (Appalachian), as shown below. This allows the database to be relevant to a greater number of LCCs and their partners. Many monitoring programs are national or regional in scope or operate within non-geopolitical geographic boundaries such as the Gulf of Mexico, such that monitoring sites often cross state lines. The GCMP region encompasses all of 11 states/territories – Arkansas, Louisiana, North Carolina, Tennessee, Mississippi, Alabama, Georgia, Florida, South Carolina, US Virgin Islands, and the Commonwealth of Puerto Rico – and portions of seven others – Texas, Oklahoma, Missouri, Virginia, Kentucky, Illinois, and Kansas.

Geographic region of the Global Change Monitoring Portal.

Develop classification scheme for monitoring programs and sites. We developed a template for common metadata to describe general aspects of monitoring programs/observational networks. Metadata describes details such as purpose of sampling, geographic area sampled, name and type of sponsor, begin and end dates, and URLs for program description and data access. As part of the metadata template, we developed a general classification scheme for categorizing the observations made by monitoring programs, with the goal to develop a scheme that is broad enough to describe types of observational data collected by disparate networks, but at a level of detail to allow users from different disciplines to find programs and data relevant for their purpose. The scheme classifies an observation according to the following categories:
(a) Media Type – the abiotic component of ecosystem in which a measurement is made,
(b) Measurement Type – what category of ecosystem property is measured, and
(c) Types of Parameters measured within those Measurement Types. Fairly broad categories are used, with definitions and examples provided to guide the user.
The classification scheme was developed by drawing upon elements of classifications used by organizations such as EPA's STORET, USGS's NWIS, ITIS, as well as input by subject experts at NC State University.

Measurement classification scheme for Global Change Monitoring Portal.

Measurement Category				
Media Type	**Measurement Type**	**Biological Parameter Type**	**Chemical Parameter Type**	**Physical Parameter Type**
Air	Biological	Ecosystem	Metals	Habitat
Land	Chemical	Fauna	Nutrients	Hydrologic
Water	Physical	Flora	Organic	Land cover
		Other Biological	Other Chemical	Meteorological
				Soil/Sediment
				Surface elevation
				Other Physical

One of the intended capabilities of the metadatabase and portal is to allow a user to find programs and data based on the locations of measurement sites, so we incorporated georeferenced detail for the locations where measurements are made, when available. The site locations are then assigned to specific geographic criteria by the mapping software. Weighing the anticipated needs of our users and complexity of design, we chose to categorize locations by State/Territory, Landscape Conservation Cooperative, Level III Ecoregion, and 8-digit Hydrologic Unit. These geographic criteria as well as the measurement categories form the basis for search criteria.

Develop pilot database and user interface. We worked with a development team of USGS staff at the Fort Collins Science Center to determine the best platform for the metadatabase. After beginning preliminary design using the ScienceBase infrastructure, we moved to development using third party software and tools, primarily open source software, to allow more flexibility in the design. These include: PostgreSQL Relational Database, Apache/Tomcat Web/Application Server, Grails Web Development Framework, ESRI ArcGIS API for Javascript, and ESRI ArcGIS Server. The GCMP is hosted at USGS Core Science Application Hosting Center. Input to developers for design of the web interface for display and search of the metadatabase was accomplished by reviewing and evaluating existing data portals and websites to identify features and capabilities for our application. Some of those evaluated include: https://my.usgs.gov/lfg/main/index, http://www.centralvalleymonitoring.org/map, http://mercnet.briloon.org/search, http://ecosystems.usgs.gov/maris/index.jsp, http://water-cat.usf.edu/, https://my.usgs.gov/crcwc/. The Southeast Coastal Water Quality Monitoring Metadata Portal, http://www.gcrc.uga.edu/wqmeta/, and the research group at the University of Georgia who developed that project for National Park Service were especially useful in consulting on aspects of our database and portal.

After initial development, we chose nine monitoring programs that spanned a broad range of measurements to populate the database, and solicited review of this pilot by representatives from the monitoring programs as well as LCC leaders, SE CSC staff, and other colleagues. We developed a review response form in order to get feedback about targeted aspects of the design and functions, and revisions to the database and web portal were made in response to review comments. Development and testing to improve display and search of information by measurement-specific and geographic criteria continued as we worked with additional program and site metadata.

Populate the GCMP. An evolving list of monitoring networks for potential inclusion in the GCMP is maintained as a working spreadsheet. Our procedures included drafting initial metadata for a program using available online or other information resources and sending for review by program representatives along with request for specific monitoring site locational information. In some cases program entries are entered in the database, then sent for review. Some site information was harvested directly from large data warehouses such as Forest Inventory and Assessment and National Water Information System or other data portals, or we encouraged program representative to provide it in an accessible format, then modified it to fit the site metadata template developed for the project for batch upload to the GCMP.

Effort on the following tasks originally proposed was pushed back to Phase 2 of the project, to allow focus on obtaining metadata for as comprehensive a set of programs and sites in the GCMP as possible:

d) Assess currently available information for use in tracking regional trends, or running scenarios of interest to federal, state, and local resource managers;
e) Identify key information gaps of concern to federal, state, and local resource managers.

6. PROJECT RESULTS:

A public-facing database containing metadata, including monitoring site and data access information, about atmospheric, terrestrial, and aquatic measurements collected in the southeastern US for observational networks, and a web application that allows the database to be queried and displayed using four geographic categories and several measurement classification categories, was developed and deployed at https://my.usgs.gov/gcmp.

Using an evolving list of monitoring programs of more than 300 programs, we gathered and sought program metadata and site information, and populated the database with entries as information was developed and reviewed. At the end of this phase of the project, there were about 100 programs in the database and about 220,000 associated measurement sites. We also continued to identify other observational networks for potential inclusion.

7. ANALYSIS AND FINDINGS:

Findings and major discoveries for the project will be synthesized at the end of Phase 2.

8. CONCLUSIONS AND RECOMMENDATIONS:

Initial design of the relational database storing monitoring program metadata did not maintain multiple relationships among Media Type (Air, Land, Water) and Measurement Type (Biological, Chemical, Physical). When necessary, we divided program entries into components by Media Type in order to enable accurate results for searches for data of a specific Measurement Type in a particular Media Type. Incorporation of these parameter relationships into the database structure would simplify data entry into the portal and potentially streamline the web interface.

In the case of large data warehouses, development of metadata harvesting procedures to automate deriving metadata from their data repositories and conversion into the format required for entry in the GCMP would be a very useful component for metadata processing. This would not be practical for smaller data sources. Methods to take advantage of web services being developed by many programs in order to make their data accessible might be profitable.

Next steps for the project include:

- Continue to expand and refine the list of monitoring programs/observational networks to potentially include in Global Change Monitoring Portal. Use this evolving list to continue to populate database with information for additional programs and sites.
- Make revisions to program and site information as necessary, and consider additional development of functionality, within project objectives and project budget.
- Use the information centralized in the GCMP to contribute to assessment of monitoring resources in the Southeast, i.e., to put the inventory into context of the big picture of data needs for accomplishing the mission of different organizations in the Southeast and for landscape-scale conservation and adaptation strategies.
- Based on user input, evaluate if this is a tool that should undergo further development/updates or potential expansion to other CSC regions.

9. MANAGEMENT APPLICATIONS AND PRODUCTS:

We expect that the Global Change Monitoring Portal will be used by individuals in various capacities and organizations to identify specific biotic and abiotic data resources collected in aquatic and terrestrial ecosystems in a particular area of interest. The GCMP could especially be utilized in evaluating regional

changes in ecosystems resulting from changes in climate and land use and in developing and monitoring landscape-level conservation strategies.

We worked with many land managers, administrators, and decision-makers, as well as field personnel and data managers, to solicit input during this phase of the project, for the following purposes: a) recommend specific data platforms and capabilities for the GCMP design; b) identify/recommend appropriate observational networks to include in the GCMP; c) identify best contacts for specific monitoring programs; d) provide information and details about specific monitoring programs and measurement locations.

We solicited review of a beta version of the GCMP from the following individuals, and incorporated revisions based on their feedback:

Organization or Monitoring Program	Name
Forest Health Monitoring Program	Borys M. Tkacz, Bill Burkman
Georgia Coastal Ecosystems Long Term Ecological Research Climate Monitoring	Wade Sheldon
Long-Term Soil Productivity Network	Andy Scott
National Atmospheric Deposition Program National Trends Network	David Gay
National Benthic Inventory Program	Cynthia Cooksey
National Status & Trends Program Bioeffects Assessment and Mussel Watch	Greg Piniak
North Carolina Division of Water Resources Monitoring Well Network	Nat Wilson
Project BudBurst	Sarah Newman, Sandra Henderson
Southeast Coast Network Salt Marsh Elevation Monitoring	Joe DeVivo
Southeast Climate Science Center	Ryan Boyles, Adam Terando, Elda Varela Minder, Aranzazu Lascurain
South Atlantic LCC	Ken McDermond, Rua Mordecai
Gulf Coastal Plains and Ozarks LCC	Greg Wathen
Peninsular Florida LCC	Tim Breault
Caribbean LCC	Bill Gould
Gulf Coast Prairie LCC	Bill Bartush
USGS Water Science Center	Michelle Moorman
USGS Patuxent Wildlife Research Center	Don Cahoon

Joe DeVivo from the National Park Service, and Merryl Alber and especially Wade Sheldon from University of Georgia, were especially helpful at the outset of the project in consultations about various aspects of design and development of the Southeast Coastal Water Quality Monitoring Metadata Portal.

10. OUTREACH:

Global Change Monitoring Portal URL: https://my.usgs.gov/gcmp.

Project website on Southeast Climate Science Center website: https://globalchange.ncsu.edu/secsc/resources/southeast-global-change-monitoring-portal/

Poster Presentation: Cari Furiness, Damian Shea, and Gerard McMahon, Development of a Global Change Monitoring Portal: Pilot Project for the Southeastern US. Poster presented at the Southeast Climate Science Center grand opening, 1/22/2014.

Webinar Presentation: Development of a Global Change Monitoring Portal: Pilot Project for the Southeastern US, Cari S. Furiness, NCCWSC Climate Change Science and Management Webinar Series, 8/26/2014.

Seminar Presentation: Development of a Global Change Monitoring Portal: Pilot Project for the Southeastern US, Cari S. Furiness, Triangle Climate and Landscape Researchers' Brown Bag, 11/13/2014.

Project results are communicated on an ongoing basis in conversations with partners and especially program representatives when soliciting information about observational networks and measurement sites. In the next phase of the project, we plan to hold a webinar for LCC representatives and other partners to solicit directed feedback on the Global Change Monitoring Portal.